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Does Santa Claus exist?

Applying statistical methods to assess gift-giving patterns: a case study in hypothesis testing by **Iris Tsouknida** and **Electra Tsouknida**

Is Santa Claus real? As 12- and 14-year-old sisters who love science, we've started to wonder. We used to listen for sleigh bells on Christmas Eve without a doubt in our minds – but now, a few years older (and a few statistics lessons wiser), we thought it might be time to put the question to the test.

So, last Christmas, instead of just waiting by the fireplace, we decided to run an experiment. Our idea started one December afternoon while decorating the tree. We were debating (as usual) about why Santa looked so different in every movie – sometimes older, sometimes thinner, sometimes even without

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a beard – a debate that somehow turned into a much bigger question: does he even exist?

We invited our friends from school and other activities to help. Our idea was simple: if Santa exists, he should have preferences of his own, just like everyone else – a preferred colour or a favourite sweet (in line with his well-documented sweet tooth). So we asked our friends to post their usual letters to Santa, requesting whatever gift they wanted, but with one small catch: they had to include the following line at the end of their letter: "Dear Santa, please bring me my gift in your favourite colour and let me know what your favourite sweet is." Of course, we didn't tell the parents what we were testing – otherwise they might have "helped" Santa a little too much. This way, only we knew which clues had been added, helping us reduce bias in our results.

It might sound a little over the top for a holiday project, but it's important nonetheless, especially when considering that children perceive and experience truth within the context of their moral and social understanding.[1] After all, much of childhood is shaped by moments where reality and imagination blend, for example in folktales, myths, or bedtime stories. The question of whether Santa is real, although most adults might think it trivial, marks a milestone in how we learn to think critically,[2] and how families pass on stories that shape childhood itself.[3]

Some contemporary philosophers would describe the search for the truth about an objective reality as metaphysics,[4] but others would advocate for a more empirical approach,[5] while some think reality depends on perception, that is to say, past visual and tactual experiences.[6] In other words, children (like us) might see "truth" differently from adults, because experience changes how we balance imagination and evidence. There is also a great deal of scientific literature on the significance of Santa Claus as a sociological concern.[7] Even deciding to stop believing in Santa just because we can't "prove" he's real, opens up a new question: are we rejecting one belief or replacing it with another? Does the very lack of evidence mean he can't exist? We believe that this kind of reasoning makes the Santa question surprisingly philosophical.

Metaphysical theorising, however, remains intellectually important because it underlies how science frames its questions – even though science itself relies on empirical testing.[8] And while many might think philosophy and science don't mix, the two actually work best together: we should ask "big questions" (like philosophers) but answer them by collecting data and testing ideas carefully (like scientists).[9] And that's exactly what we tried to do. We approached the question of Santa Claus's existence from a rigorous empirical standpoint, grounded in statistical analysis and a clear hypothesis framework.

We tested two competing hypotheses, framed around the nature of gift-giving patterns. A seemingly simple addition to our own – and our friends' – letters to Santa about his own preferences was likely to go unnoticed by the unsuspecting gift giver. However, this subtle inclusion should result in a decisive gift-giving pattern, potentially indicative of Santa's existence – or lack thereof.

The null hypothesis (H_0) of the study was that all gifts are chosen by parents. Under this scenario, the distribution of gift features, such as colour and associated sweets, would reflect the diverse and culturally influenced preferences of the parents. Consequently, the observed combinations of colour and sweet would vary significantly across families, with no single combination dominating beyond what is expected by chance.

The alternative hypothesis (H_A) was that some (not all) gifts are indeed delivered by Santa Claus. In this case, a fraction (θ) of families would receive gifts characterised by a consistent combination of colour and sweet, chosen according to Santa's uniform preferences. This would result in a significant clustering of a specific colour–sweet pair, distinguishable from the expected variability under the null hypothesis, which was accounted for in the $1 - \theta$ fraction of remaining families, based on a pilot survey of parental preferences in colour and sweets.

How did we do it?

The study was designed to allow for the possibility that only a fraction θ of participating families might receive presents directly from Santa (i.e., the "Santa scenario"), while the remainder ($1 - \theta$) receive parent-selected gifts (the "no Santa" scenario). This notion is based on cultural variance among the participating families and the fact that some of them may have holiday traditions foreign to Santa Claus, prompting parents to step in to prevent their children from feeling left out. Consequently, Santa may only visit a subset of homes, while others rely on parent-chosen gifts – choices that may, however, themselves reflect biases in colour or sweet selection. The statistical approach of our study did therefore account for this partial Santa scenario.

While parents' selections could, in theory, be influenced by their children's wishes or by assumptions about Santa's taste, our experimental design limited this bias as the parents were unaware that colour and

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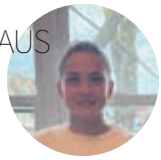

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sweet preferences were being recorded, and the pilot survey was conducted to establish expected parental patterns on a separate group of families.

To detect the influence of a universal gift giver (i.e., Santa Claus), we tried to identify whether a single colour–sweet combination (e.g., red + chocolate) appeared significantly more often than would be expected, that is, if all gifts were chosen by parents alone. All received gifts were categorised in one of ten colour ranges (black, blue, brown, green, red, pink, purple, yellow, orange, white), and similarly in one of ten sweet types (pumpkin pie, chocolate, cookies, gingerbread, panettone, Christmas stollen, candy, yule log, cake, other). This grouping assumes that nearby shades or similar treats fall within the same category – a simplification that, while necessary for analysis, should also represent a stricter assumption in our statistical treatment.

Sample size calculation

The highest probability of any single colour–sweet combination under strictly parent-based choices was denoted by p_{max}. For instance, if red + chocolate is the most common parental choice at 5%, then p_{max} = 0.05. Similarly, if Santa always provides one particular colour–sweet pair, the effective probability of observing that pair in the mixture scenario is given by $p_{alt} = \theta + (1 - \theta)\, p_{max}$. This formulation also accounts for cases where Santa's preferred colour or sweet may not be available for a particular gift, since such gifts would be represented within the $1 - \vartheta$ fraction. Thus, even if θ represents only a modest fraction of families considered within this experiment (e.g., 20%), p_{alt} is still expected to substantially exceed the value of p_{max}.

We should note that the use of p_{max} represents a conservative assumption corresponding to the least favourable case, where Santa's favourite combination coincides with the most common parental choice, thereby reducing the likelihood of false positives.

Under the null hypothesis of "no Santa", the most frequent colour–sweet combination in the data should arise from parent choices alone, with probability p_{max}. If X is the count (out of N children) who receive that single combination then $X \sim \text{Binomial}(N, p_{max})$.

A significance level $\alpha = 0.05$ was used to identify a critical count x^*, such that

$$P\{X \geq x^*\} = \sum_{k=x^*}^{N} \binom{N}{k} (p_{max})^k (1 - p_{max})^{N-k} \leq 0.05$$

If *at least* x^* children receive the same colour–sweet combination, the result is deemed "statistically unlikely" (at the 5% level) under the null hypothesis.

To ensure that the experiment reliably detects Santa, even if he only visits a fraction θ of homes, a power analysis was performed. Under the "Santa scenario" (i.e., partial Santa involvement in the gift-giving process), each gift has probability p_{alt}. Hence, $X \sim \text{Binomial}(N, p_{alt})$. The power of this test is the probability of correctly rejecting the null hypothesis when the alternative is true:

$$\text{power} = P(X \geq x^* \mid X \sim \text{Binomial}(N, p^{alt})).$$

A target value (80%) was selected to ensure a high likelihood of detecting Santa's influence, if indeed a θ fraction of families are visited.

Based on a pilot survey implemented to account for variability under the null hypothesis (results are presented in Table 1), we assumed for planning purposes that the single most popular colour–sweet pair among parents was 5% (p_{max} = 0.05), as a conservative anchor consistent with the pilot marginals. This choice affected only the *a priori* power calculation, while the hypothesis tests reported below use the observed counts and do not depend on any independence assumption which was used only for illustrating expected combinations, and not for any statistical testing.

In the choice of θ, a conservative scenario was posited, in which Santa visits only θ = 20% of the sampled homes.

Based on this analysis, a sample size of N = 30 was chosen for the study, as it satisfied both the false-alarm constraint ($\alpha \leq 0.05$)

Table 1: Probabilities of colour and sweet preferences based on a pilot survey of parental preferences (87 responses of parents whose children were not included in the actual study). Preferences were recorded independently rather than as fixed pairs, so the data are presented as marginal distributions rather than a full cross-tabulation

Colour	Probability (%)	Sweet	Probability (%)
Red	20	Chocolate	25
Blue	17.5	Cookies	20
White	15	Cake	15
Black	13.75	Gingerbread	11.2
Green	8.75	Panettone	7.5
Brown	7.50	Christmas stollen	5
Yellow	6.25	Candy	3.8
Pink	5	Yule log	2.5
Purple	3.75	Pumpkin pie	2.5
Orange	2.50	Other	7.5

Table 2: Distribution of colour and sweet combinations observed in gifts after Christmas Eve. The table summarises the frequency of each colour–sweet combination, highlighting patterns consistent with Santa's uniform preferences (if any) and the variability documented through the pilot survey of parental preferences. Numbers in parentheses denote total count for each colour/sweet

	Black (8)	Red (7)	Blue (7)	White (3)	Pink (3)	Purple (2)
Chocolate (8)	1	2	3	1	1	–
Cookies (6)	2	1	2	–	–	1
Candy (2)	1	1	–	–	–	–
Cake (3)	1	1	–	1	–	–
Gingerbread (1)	–	–	–	–	1	–
Christmas stollen (2)	1	–	–	1	–	–
No response (5)	2	1	1	–	1	–
Other (3)	–	1	1	–	–	1

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Table 3: Observed and expected frequencies of gift colours based on the pilot survey and chi-square analysis

Colour	Observed	Expected
Black	8	4.13
Red	7	6.00
Blue	7	5.25
White	3	4.50
Pink	3	1.50
Purple	2	1.13
Other	0	7.50

Table 4: Observed and expected frequencies of sweets based on the pilot survey and chi-square analysis. The "no response" category was not included in the chi-square test

Sweet	Observed	Expected
Chocolate	8	7.50
Cookies	6	6.00
Candy	2	1.20
Cake	3	4.50
Gingerbread	1	3.30
Christmas stollen	2	1.50
No response	5	0.00
Other	3	3.00

and the desired power requirement (i.e., for $\theta = 20\%$, $p_{alt} = 24\%$ and thus $P(X \geq 4) = 1 - P(X \leq 3) = 1 - 0.048 = 95.2\%$).

Evaluation of results

To assess whether the overall distribution of colour–sweet combinations that were received matched the expected distribution under H_0, a chi-square test was conducted. The presence of significant clustering of specific combinations was examined using a contingency table. Observed patterns were tested for uniformity against expected frequencies, allowing for detection of any disproportionate representation indicative of Santa's influence.

What did we find?

Following Christmas Day, the young participants were asked to report the colour and sweet combinations they received. The observed distributions differed significantly from the parental preferences documented in the pilot survey. The most frequently occurring gift colour was black (8), followed by red (7) and blue (7), with all gifts categorised into six colour choices. Sweet preferences showed a strong skew towards chocolate (8), closely followed by cookies (6). Notably, five stockings did not indicate a sweet preference, introducing a new "no response" category. The distribution of colour and sweet combinations, along with the frequency observed for each, is summarised in Table 2.

To evaluate whether the observed distributions deviated from the expected distributions under H_0, chi-square tests were conducted separately for colour (Table 3) and sweet preferences (Table 4). For colours, the chi-square statistic was 14.57 with a p-value of 0.024, indicating a statistically significant deviation from the expected distribution ($\alpha = 0.05$).

In contrast, the chi-square test for sweets yielded a chi-square statistic of 3.57 and a p-value of 0.735, showing no significant deviation between the observed and expected frequencies. The "no response" category for sweets, introduced during the study, was excluded from the statistical analysis as it had no corresponding expected value in the pilot survey.

Examining the results

With a lingering sense of disappointment, we acknowledge that the results of this study advocate against the existence of Santa Claus, as statistical analysis did not reveal patterns indicative of a uniform external influence consistent with H_A (i.e., $X < 4$). The most frequent colour–sweet combination, blue + cookies, did not display a uniform trend consistent among participants. As a result, no single colour–sweet combination surpassed the critical count required to provide strong evidence against the null hypothesis.

Despite this, the observed frequencies in gift colours varied from the expected ones, with the chi-square test (Table 3) revealing significant clustering ($p = 0.024$), which warrants further discussion. In contrast, the chi-square test for sweet preferences (Table 4) yielded a p-value of 0.735, showing no significant deviation from the expected distribution. It is important to note, however, that five participants were not able to report a sweet preference for Santa. These "no response" cases reduced the effective sample size for the sweet analysis from 30 to 25, thereby lowering the statistical power of the test and increasing the uncertainty around the estimated frequencies. While the exclusion of these responses was necessary – since no corresponding expected category existed in the pilot data – it may partly explain the absence of any significant pattern for sweets. A more complete data set could have provided a clearer comparison between colour and sweet distributions.

The higher than expected repetition of black and blue gifts is, however, worth further consideration. Black, as a colour frequently observed in commercial merchandise and gifts, may reflect traditional gift-giving patterns rather than an external influence. Blue, on the other hand, could be attributed to the "blue–seven phenomenon",[10] a cognitive bias where blue is disproportionately favoured as a colour choice in various contexts. Conversely, the lack of other colours among the gifts, such as green and brown, might be explained by the limited availability of certain types of gifts in these colours, suggesting that market availability rather than Santa's preferences influenced the observed outcomes.

Whether driven by genuine metaphysical curiosity or concerns regarding the societal implications of perpetuating myths like Santa Claus,[11] this topic has been extensively examined across various academic disciplines, including psychology[12] and sociology.[13] In exploring the metaphysical aspects of Santa's existence, this study exemplifies the application of scientific reasoning to questions traditionally deemed metaphysical. This approach underscores the significance of evidence-based inquiry, even when addressing whimsical or culturally ingrained subjects, and illustrates how structured methodologies can inform and engage broader societal discussions.[14] Moreover, it serves as a valuable educational opportunity for young children, who, upon reaching an appropriate age, can transition from mythical beliefs to scientific understanding, thereby mitigating the disappointment often associated with demystifying childhood beliefs.

As already mentioned, our study is not without limitations. The most notable one concerns the treatment of colour and sweet preferences as independent variables in the

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pilot survey, which restricted our ability to analyse their joint distribution. Additionally, the modest sample size and the possibility of parental influence (i.e., the conspiring parents scenario) add uncertainty to our results. As discussed above, a small number of missing sweet responses further reduced the effective sample size for that variable and may have contributed to the limited sensitivity of the sweet-related analysis. Future studies could address these limitations by recording paired colour–sweet combinations and ensuring complete response data, allowing for a more comprehensive evaluation of potential patterns.

So, is Santa real?

It is important to note that, while the results of this study are irrefutable, they should not be mistaken for proof against Santa's existence. We maintain our right to object – perhaps to our own inexperience in accounting for certain variances or to the possibility that our methodologies lacked the sophistication required to detect truly magical phenomena. In statistical terms, failing to find a pattern of colours and sweets strong enough to confirm the influence of either a universal gift giver (i.e., Santa) or conspiring parents does not mean we have proven the absence of such forces – it simply means that our data was not sufficient to rule out more ordinary explanations, such as coincidental choices or parental involvement.

In clear defiance of our ambition to uncover the truth, we invoke the spirit of Rudolf Carnap, who argued that metaphysical beliefs (maybe even like Santa Claus, although likely not what he had in mind) are expressions of personal conviction rather than propositions to be disproven.[15] Thus, we steadfastly maintain our belief in the magical foundation of Christmas, ultimately embracing the idea that some questions might, or even should, transcend empirical scrutiny.

Acknowledging the importance of personal growth (scientific and otherwise), we pledge to revisit this issue in the future and consider the positive exposure to scientific reasoning as the true takeaway of the study, rather than merely "demystifying" Santa. In closing, we remain undeterred in our faith in the extraordinary and eagerly anticipate the holiday season, fully expecting our gifts to once again surpass our parents' capacity for gift-giving. ■

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